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(54) Title: OPTICAL DIFFRACTION VELOCIMETER

(57) Abstract

A laser velocimeter for measuring the relative speed of a surface and a source of coherent light directed at the said surface comprising optical and electrical means for generating two electrical signals one of which corresponds to the content of the speckle pattern produced by illumination of the surface by the light circuit means for obtaining a difference signal from the two electrical signals and frequency measuring means for determining the centre frequency of the signal spectrum of the difference signal to generate an electrical signal indicative of the relative velocity of the surface and source. The device can measure length or distance moved by integrating the velocity signal. The optical and electrical means include a grating in the path to one of two detectors or a linear array of photodetectors alternate ones of which are summed, to provide the two electrical signals one of which corresponds to the speckle pattern.

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# Optical diffraction velocimeter

## Field of Invention

This invention concerns measuring instruments and particularly instruments for measuring speed of movement and thereby distance travelled.

## Background to the invention

It is known that a speckle pattern is formed by the interference of coherent light scattered from a diffuse object and that the pattern moves with a velocity proportional to the object velocity and can be detected to produce an electrical signal proportional to speed. Such a device is commonly referred to as a laser velocimeter. The basic principle of operation and typical construction of such a device is contained in the paper entitled Optical Diffraction Velocimeter by G. Stavis published in Instruments and Control Systems in February 1966 at page 99.

A development of such a system using optical fibre and a graded index rod lens is described in a later paper entitled Laser Speckle Velocimeter utilising Optical Fibres by A. Hayashi and Y. Kitagawa published in Optics Communications, Volume 43 No. 3 of 1st October 1982.

These references are merely examples of a large number of papers which have been published on the various studies

made into the effects of illuminating a moving surface using coherent light and measuring the velocity of the resulting speckle pattern.

It is a primary objective of all measuring systems to reduce as far as possible, all influences which can affect the measurement and which do not contribute to the parameter within the system which is being observed and measured. To this end in a laser velocimeter it is desirable if possible, to remove any static and low frequency components of the speckle pattern and limit the component of the signal to be measured to that of the frequency associated with the movement. In this way the instrument can be rendered generally insensitive to variations in overall light level, changes in ambient light and conditions, and variation in the surface from which the light is reflected.

This can be achieved by forming an optical inverse of the speckle pattern (or an electrical inverse of an electrical signal corresponding to the original speckle pattern) and combining the inverted optical signal (or inverted electrical signal) with the appropriate original signal. This reduces any so called DC component and tends to leave only time varying components in the signal.

Whilst this is in effect achieved by the fibre optic system paper by Hayashi and Kitagawa, the difficulty of aligning the optical fibre elements does not allow this particular method to be adapted to a versatile speed measuring system capable of being used in industrial environments and the like.

A different approach involves the use of two interlaced

gratings so that the phase of the speckle signal received by a detector associated with one of the two gratings is out of phase with the signal received by a second detector, associated with the other of the two gratings. Again the difficulty in practice of aligning the two gratings means that this approach has also proved impractical for a general purpose instrument.

It is an object of the present invention to provide a laser velocimeter which is simple to construct and does not involve precise alignment, as for example, do the two systems described above.

It is a further object of the invention to provide a length/distance measuring device which incorporates the improved laser velocimeter of the invention.

## Summary of the invention

According to one aspect of the present invention, a laser velocimeter comprises:

a) a coherent light source of known wavelength directed at a moving surface the speed of which is to be determined,

b) beam splitting means which receives light reflected from the said surface and directs it into two different channels,

c) first light responsive detector means for generating a first electrical signal from the light in one channel,

d) second light responsive detector means for generating

a second electrical signal from the light in the other channel,

e) an optical grating interposed in the light path of one of the channels with the plane of the grating substantially perpendicular to the direction of the light in that channel and with the grating lines transverse to the direction of movement of the speckle pattern in the channel containing the grating,

f) electrical signal processing means for combining the signals from the two detectors so as to obtain a difference signal therefrom, and

g) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

The speckle size is proportional to the wavelength of the light producing the speckle pattern and the size of the speckles varies around a mean value on a statistical basis. The line pair spacing in the grating is preferably selected so as to correspond to the mean speckle size expected for the known wavelength of the coherent light source.

From the work done by Stavis, it can be shown that if:
F is the centre frequency
N is the number of line pairs per cm of the grating, and
v is the velocity of the surface in cm's per second, then
$v = F/2N$ cm per second.
(ie v is proportional to the centre frequency).

Thus it can be seen that by simply calibrating a visual display indicating the output of the frequency measuring means, so a direct reading of speed can be obtained.

By summing the electrical signal indicative of velocity so a signal equivalent to distance travelled by the reflecting surface relative to the source can be obtained.

Where the reflecting surface is a long length of an elongate member such as wire the distance signal will be proportional to the length of the elongate member which has passed relative to the source.

It will be seen that a device embodying the invention will function whether the surface producing the speckle pattern is moving relative to the coherent light source and detectors, or vice versa.

Conveniently, the detectors are each photoelectric devices such as semi-conductor junctions.

Preferably the output signal from at least one of the detectors is amplified by signal amplifying means having adjustable gain, and the signals from the detectors (via the adjustable gain amplifier(s)) are supplied to the input of a differential amplifier, and the output of the differential amplifier can be nulled in the absence of signals from the beam splitting device (ie with the laser off or blocked) or in the absence of a reflective surface, by adjusting the gain of the adjustable gain amplifiers.

Preferably means is provided for shaping the wave form of the electrical signal pulses obtained from the processing

means.

Conveniently the frequency measuring means is a phase locked detector or similar.

According to another aspect of the invention a method of determining the velocity of a moving surface from which a speckle pattern image can be obtained by reflection of light from a coherent light source of known wavelength comprises the steps of:

a) directing light of known wavelength from a coherent light source onto the surface so as to be reflected therefrom as a speckle pattern,

b) collecting the reflected light in a beam splitting device to direct the light into two different channels,

c) causing the light in one of the two channels to pass through an optical grating, the line pair spacing of which is selected in dependence on the wavelength of the coherent light,

d) detecting the light in each of the two channels so as to produce two electrical signals,

e) combining the two signals using a differential amplifier,

f) determining the mean frequency of the signal spectrum in the output of the differential amplifier, and

g) displaying a value proportional to the measured frequency, as a velocity signal.

According to another aspect of the present invention, a laser velocimeter comprises:

a) a coherent light source of known wavelength directed at a surface the speed of which relative to the source is to be determined,

b) a reflecting grating means which receives light reflected from the said surface and splits it into two different channels, the plane of the grating being substantially perpendicular to the direction of the light and with the grating lines transverse to the direction of movement of the speckle pattern,

c) first light responsive detector means for generating a first electrical signal from the light in one channel,

d) second light responsive detector means for generating a second electrical signal from the light in the other channel,

e) electrical signal processing means for combining the signals from the two detectors so as to obtain a difference signal therefrom, and

f) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

The output signal relating to frequency may be an analogue signal of which typically the amplitude varies with frequency and an analogue measuring device such as a

moving coil meter display or the like may be used to indicate the mean frequency measured. By suitable calibration the instrument can give as a direct reading the velocity of the reflecting surface.

Further apparatus and/or a further method step may be provided to convert the signal from an analogue form into a digital form for display in a digital display device such as a liquid crystal display device or the like. Again using suitable calibration, the digital signal can be in the form of a direct reading of velocity.

The beam splitting device may take any convenient form and whilst it is generally desirable that the available light is split approximately 50/50 between the two channels it will be appreciated that since the speckle pattern in each channel is converted into an electrical signal it is possible to compensate for a different split between the light levels in the two channels by appropriate adjustment of the gain of signal amplifying means responsive to the electrical signals generated by the detectors in the two channels.

According to another aspect of the present invention, a laser velocimeter comprises:

a) a coherent light source of known wavelength directed at a surface the speed of which relative to the source is to be determined,

b) a reflecting grating means which receives light reflected from the said surface and splits it into two different channels, the plane of the grating being substantially perpendicular to the direction of the light

and with the grating lines transverse to the direction of movement of the speckle pattern,

c) first light responsive detector means for generating a first electrical signal from the light in one channel,

d) second light responsive detector means for generating a second electrical signal from the light in the other channel,

e) electrical signal processing means for combining the signals from the two detectors so as to obtain a difference signal therefrom, and

f) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

According to a further aspect of the invention a laser velocimeter comprises:

a) a coherent light source of known wavelength directed at a surface the speed of which relative to the source is to be determined;

b) a receiver adapted to receive light reflected by the said surface and comprising a linear array of photosensitive elements with the outputs from alternate elements summed to form two electrical output signals, the spacing between each adjacent pair of elements being selected so as to correspond to the mean speckle size for the given wavelength,

c) electrical signal processing means for combining the two electrical signals to obtain a difference signal therefrom, and

d) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

Each of these last mentioned embodiments has the advantage that a strong electrical signal is obtained and, in the case of the last embodiment mentioned only a few components are required albeit the photosensitive element array being a special-purpose component.

Where the frequency of the signal indicative of velocity is the parameter thereof which varies with velocity, then a measure of length is most simply obtained by integrating the signal indicative of velocity with respect to time.

Where the velocity signal is a pulse train the frequency of which varies with velocity the integrator may simply comprise a pulse counter.

A display is preferably provided responsive to the integration signal (or accumulating count value) to indicate the distance or length. The display may be analogue or digital.

According to a preferred feature of the invention the differential electrical output signal is filtered by a bandpass filter to restrict the frequency content of the signal to dynamic range of interest.

According to another feature of the invention the filtered signal is passed through a so-called tracking filter typically a high pass filter, where bandwidth is determined by subsequent frequency to voltage converter means, whereby the dynamic characteristics are such that the pass band increases if the signal is lost.

According to another feature of the invention the tracking-filter output constitutes the input signal for a frequency to voltage converter means whose output is an approximation of the signal frequency for feeding back to the tracking filter and forward to a phase locked loop detector.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic view of a known type of laser velocimeter,

Figure 2 illustrates graphically the power/frequency distribution in the signal supplied to the frequency analyser,

Figure 3 illustrates a more acceptable form of power to frequency curve such as can be obtained by using the present invention,

Figure 4 illustrates diagrammatically one embodiment of the present invention,

Figure 5 illustrates another embodiment of the present invention,

Figure 6 illustrates a further embodiment of the present invention, and

Figure 7 is a circuit diagram of the signal processing means and velocity signal generating circuit.

Detailed description of the drawings

In Figure 1 a laser light source 10 of known wavelength is directed towards a moving diffuse surface 12. Light reflected from the surface produces a speckle pattern which is intercepted by an optical grating 14. The lines of the grating are transverse to the direction of movement of the speckle pattern.

The latter produces an electrical signal in the output of a photodetector 16, the position of the detector and grating 14 being selected so that the distance of the image of the speckle pattern from the surface 12 is the same as the distance from the source 10 to the surface 12.

The output from the photodetector is analysed using a frequency analyser 18 and if displayed on a cathode ray display device such as 20 a frequency/power distribution curve will be obtained such as is shown in Figure 2.

From the formulae developed by Stavis, the frequency F is given by 2Nv where:

N is the number of line pairs per cm in the grating and v is the velocity of the surface in cm per second.

As will be seen from Figure 2, there is a very

considerable quantity of energy in the signal spectrum from the photodetector 16 in the lower frequency band and it is an object of the present invention to produce a spectrum similar to that shown in Figure 3 to avoid problems arising from false peaks which might be detected.

In Figure 3 the low frequency content of the signal from the photodetector 16 has been largely eliminated.

In accordance with the invention, this is achieved by using different arrangements for detecting the speckle pattern and reference is now made to Figure 4. In this Figure 4 laser 10 again directs light towards the moving surface 12 and the reflected light is collected by a beam splitting device 22 which diverts approximately 50% of the light at right angles to the direct line of transmission through the device 22. Two channels of information are thus derived from the single channel of light information reflected from the surface 12.

An optical grating 24 is interposed between the in-line output of the beam splitting device 22 and a first detector 26 whilst the diverted light is supplied directly to a second photodetector device 28.

The outputs from the two detectors are amplified by means of buffer amplifiers 30 and 32 respectively and the outputs from the two amplifiers 30 and 32 are supplied to a differential amplifier 34. The gain of each of the amplifiers may be adjustable for setting up.

The output from the differential amplifier 34 is conveniently passed through a wave shaping circuit 36 so

as to produce a relatively square wave shape to any pulses released by the differential amplifier 34 and the mean frequency of any such shaped signals is determined using a phase locked detector 38. In the particular design in question, a voltage is available at a point 40 the value of which and the actual value of this voltage can be displayed using a meter type display or the like as denoted by reference numeral 42. The latter can be calibrated to give a direct reading of velocity $\underline{v}$ since from the formula quoted above it is seen that frequency F is proportion to the velocity $\underline{v}$.

Although the grating 24 has been shown in the path of the light which passes straight through the beam splitting device 22, it may of course be located alternatively in the channel containing the diverted light from the beam splitting device 22.

By providing means for varying the gain of one or both of the buffer amplifiers 30 and 32, so the outputs from the two detectors 26 and 28 can be balanced during setting up.

The operation of the circuit shown in Figure 4 is to reduce the lower frequency pedestal from the spectrum of the signals applied to the shaping circuit 36 and phase locked detector 38. The success of the circuit depends on producing a balance between the signal relating to the low frequency end of the spectrum appearing in the output of amplifier 30 and the corresponding low frequency signal from amplifier 32. To this end the outputs from the two amplifiers are adjusted so as to be approximately equal whilst the surface 12 is stationary. Movement of the surface then produces signals centred around the mean

frequency F, the actual value of which will be dependent upon the speed of the surface 12. It is a signal centred around this frequency which will appear in the output of the differential amplifier 34.

A summing amplifier can be used in place of the differential amplifier 34 if the signal from one of the detectors 26 and 28 is inverted in phase (ie through 180°) relative to the other signal.

Preferably the laser source 10 and the detector (made up of the beam splitting device 22, grating 24 and photodetectors 26 and 28) are contained in a single housing, or in two housings which are rigidly secured together, to form a unitary assembly, to avoid the need for accurately setting up the various parts of the system relative to the moving surface 12. However, it is still important that the unitary assembly be placed at a correct distance from the surface 12 so as to obtain the desired reflection of the illumination region of the surface to form the speckle pattern.

In figure 5 light from the laser 10 is reflected by the surface 12 onto a reflecting grating 44. The transmitted light falls on detector 26 and the reflected light at detector 28 which thereafter operate in the same manner as before described.

In Figure 6 the grating 24 and detectors 26, 28 are replaced by a single special purpose photosensitive elemental array 46 to which the output of alternative areas of the elements in the array are summed to provide two output signals for supply to the differential amplifier 34. This and the remainder of the system operate as

before described.

A block diagram of the signal processing circuits is shown in Figure 7. The signal processing may be considered to start at the differential amplifier 34 in Figures 4, 5 and 6.

In each embodiment the electrical difference signal is passed through a bandpass filter 48 to restrict the frequency content to the dynamic range of interest. It then passes through a tracking filter 50 which is a highpass filter whose bandwidth is determined by subsequent frequency-to-voltage converter 52. The dynamics are arranged such that the pass band increasesif the signal is lost.

The output of the tracking filter 50 is fed into a frequency-to-voltage (F/V) converter, whose output is an approximation of the signal frequency. The output of the frequency-to-voltage converter 52 is fed back to the tracking filter (see above), and forward to a phase locked loop 54 to guide it to approximately the correct frequency.

This is done by summing the F/V output signal into a voltage controlled oscillator (VCO) input of the phase locked loop, along with the phase error signal. The phase error signal is also multiplied by the F/V output signal (prior to the VCO) in order to maintain a constant ratio of tracking and lock range of the loop to centre frequency, over the whole frequency range of the instrument. This tracking and lock range prevents the phase locked loop 54 from locking to odd harmonics or subharmonics of the input signal, allowing for

inaccuracies in the F/V output signal.

This use of the frequency-to-voltage converter results in a system which is very resistant to noise but which can nevertheless cover a wide dynamic range.

The output of the phase locked loop 54 is a clean signal whose frequency is proportional to the speed to be measured. It is quite insensitive to the wide dynamic range and occasional drop-outs of the originating signal and can be fed into a display 56 for displaying velocity or to a counter 58 and thence to a display 60, whose output (suitably calibrated) indicates distance (ie length of surface 12 "seen").

Where a digital value of speed is required an analogue to digital converter 66 and digital display 68 may be provided. Likewise where a digital value of distance (length) is required, an analogue to digital converter 70 and digital display 72 may be provided.

If the speed drops below the lower end of the dynamic range of the system, then the only input will be noise, and this will tend to cause the tracking system to behave erratically. To avoid this, the signal is monitored by a level detector 62 and when the signal level drops below a pre-determined threshold the level detector causes switches A and B to change state. The input to the tracking filter (at switch A) is now an LF oscillator 64, whose frequency is chosen to be at the bottom of the acceptable dynamic range. This holds the tracking system at the lower end, ready to re-acquire the signal when it reappears.

Switch B disables the counter, ensuring that no distance is counted whilst switched A and B are in the changed state. When the level detector detects that signal is again present, switches A and B revert to their initial state and the system continues to measure speed or distance (ie length).

Claims

1. A laser velocimeter for measuring the relative speed of a surface and a source of coherent light directed at the said surface comprising

(1) means for generating two electrical signals one of which corresponds to the content of the speckle pattern produced by illumination of the surface by the light,

(2) means for obtaining a difference signal from the two electrical signals, and

(3) frequency measuring means for determining the centre frequency of the signal spectrum of the difference signal to generate an electrical signal indicative of the relative velocity of the surface and source.

2. A method of measuring relative speed of a surface and a coherent light source comprising the steps of,

(1) directing light from the source to the surface,

(2) collecting reflected light fromthe surface and generating two electrical signals from the reflected light, one corresponding to the speckle pattern produced by the illumination,

(3) obtaining a difference signal from the said signals, and

(4) determining the centre frequency of the signal spectrum of the difference signal to generate an

electrical signal indicative of the relative velocity of the surface and source.

3. A laser velocimeter as claimed in claim 1 comprising

(a) a coherent light source directed at the said surface,

(b) beam splitting means which receives light reflected from the said surface and directs it into two different channels,

(c) first light responsive detector means for generating a first electrical signal from the light in one channel,

(d) second light responsive detector means for generating a second electrical signal from the light in the other channel,

(e) an optical grating interposed in the light path of one of the channels with the plane of the grating substantially perpendicular to the direction of the light in that channel and with the grating lines transverse to the direction of movement of the speckle pattern in the channel containing the grating,

(f) electrical signal processing means for combining the signals from the two detectors so as to obtain a difference signal therefrom, and

(g) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an

electrical signal indicative of the relative speed of the surface and the source.

4. A laser velocimeter as claimed in claim 3 further comprising a visual display device for indicating the output of the frequency measuring means whereby a direct reading of speed can be obtained.

5. A laser velocimeter as claimed in claim 3 wherein the surface moves relative to the source.

6. A laser velocimeter as claimed in claim 3 wherein the source moves relative to the surface.

7. A laser velocimeter as claimed in claim 3 wherein the detectors are each photoelectric devices such as semi-conductor junctions.

8. A laser velocimeter as claimed in claim 3 wherein the output signal from at least one of the detectors is amplified by signal amplifying means having adjustable gain, and the signals from the detectors after amplification are supplied to the input of a differential amplifier, and means is provided to null the output of the differential amplifier in the absence of signals from the beam splitting device (ie with the laser off or blocked) or in the absence of a reflective surface, the null adjustment being effected by adjusting the gain of the adjustable gain amplifier(s).

9. A laser velocimeter as claimed in claim 3 further comprising means for shaping the wave form of the electrical signal pulses obtained from the processing means.

10. A laser velocimeter as claimed in claim 3 wherein the frequency measuring means is a phase locked detector.

11. A method of determining the relative velocity between a surface from which a speckle pattern image can be obtained by reflection of light from a coherent light source and the said source as claimed in claim 3, comprising the steps of,

(a) directing light of known wavelength from the coherent light source onto the surface so as to be reflected therefrom as a speckle pattern,

(b) collecting the reflected light in a beam splitting device to direct the light into two different channels,

(c) causing the light in one of the two channels to pass through an optical grating, the line pair spacing of which is selected in dependence on the wavelength of the coherent light,

(d) detecting the light in each of the two channels so as to produce two electrical signals,

(e) combining the two signals using a differential amplifier,

(f) determining the mean frequency of the signal spectrum in the output of the differential amplifier, and

(g) displaying a value proportional to the measured frequency, as a velocity signal.

12. A laser velocimeter as claimed in claim 1 comprising;

(a) a coherent light source directed at a surface the speed of which relative to the source is to be determined,

(b) a reflecting grating means which receives light reflected from the said surface and splits it into two different channels, the plane of the grating being substantially perpendicular to the direction of the light and the grating lines being transverse to the direction of movement of the speckle pattern,

(c) first light responsive detector means for generating a first electrical signal from the light in one channel,

(d) second light responsive detector means for generating a second electrical signal from the light in the other channel,

(e) electrical signal processing means for combining the signals from the two detectors so as to obtain a difference signal therefrom, and

(f) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicating of velocity.

13. A method of measuring the relative speed of a surface and a coherent light source as claimed in claim 2 comprising the steps of:

(a) directing at the said surface light from the said source,

(b) causing light reflected from the surface to be partially reflected a reflecting grating means which receives light reflected from the said surface and splits it into two different channels, the plane of the grating being substantially perpendicular to the direction of the light and with the grating lines transverse to the direction of movement of the speckle pattern produced by the light incident on the said surface,

(c) generating a first electrical signal from the light in one channel,

(d) generating a second electrical signal from the light in the other channel,

(e) combining the two electrical signals so as to obtain a difference signal, and

(f) determining the centre frequency of the signal spectrum of the difference signal, to thereby generate an electrical signal indicative of velocity.

14. A laser velocimeter as claimed in claim 1 for measuring the relative speed of a surface and a coherent light source comprising:

(a) means directing light from the coherent source towards the surface,

(b) a receiver adapted to receive light reflected by

the said surface and comprising a linear array of photosensitive elements with alternate elements summed to form two electrical output signals,

(c) electrical signal processing means for combining the two electrical signals to obtain a difference signal therefrom, and

(d) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

(e) electrical signal processing means for combining the signals from the two detectors so as to obtain a difference therefrom, and

(f) frequency measuring means for determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

15. A method of measuring the relative speed of a surface and a coherent light source as claimed in claim 2 comprising the steps of:

(a) directing the light source at the surface,

(b) collecting light reflected by the said surface on a linear array of photosensitive elements with alternate elements summed to form two electrical output signals,

(c) combining the two electrical signals to obtain a difference signal therefrom, and

(d) determining the centre frequency of the signal spectrum in the output of the signal processing means to thereby generate an electrical signal indicative of velocity.

16. A laser velocimeter as claimed in any of the preceding apparatus claims where the output signal relating to frequency is an analogue signal and an analogue measuring device is used to indicate the mean frequency measured.

17. A laser velocimeter as claimed in any of the preceding apparatus claims further comprising analogue to digital converter means for converting the analogue signal into digital form, for display in a digital display device.

18. A laser velocimeter as claimed in any of the preceding apparatus claims wherein the frequency measuring means generates an electrical signal whose frequency is indicative of the relative velocity of the surface and source and wherein there is further provided integrating means responsive to the said electrical signal, the integrated signal output of which is indicative of the length of the said surface which has passed the source, thereby to form a length measuring device.

19. A length measuring device as claimed in claim 18 further comprising a display device responsive to the integrated signal output to indicate the accumulating value of the integrated signal output as a measure of the length of the surface which has passed.

20. A length measuring device as claimed in claim 18 wherein the integrating means comprises a pulse counter.

21. A length measuring device as claimed in claim 19 wherein the display device is a digital display device.

22. A velocity measuring device constructed arranged and adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

23. A length measuring device constructed arranged and adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

24. Methods of measuring velocity and/or distance or length substantially as herein described and reference to and as illustrated in the accompanying drawings.

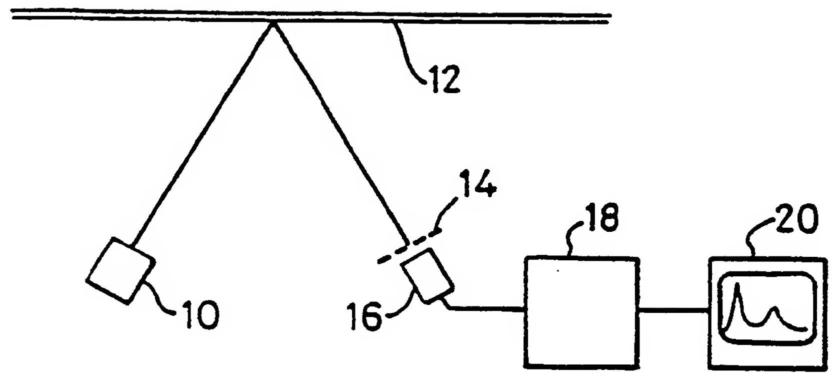


Fig.1

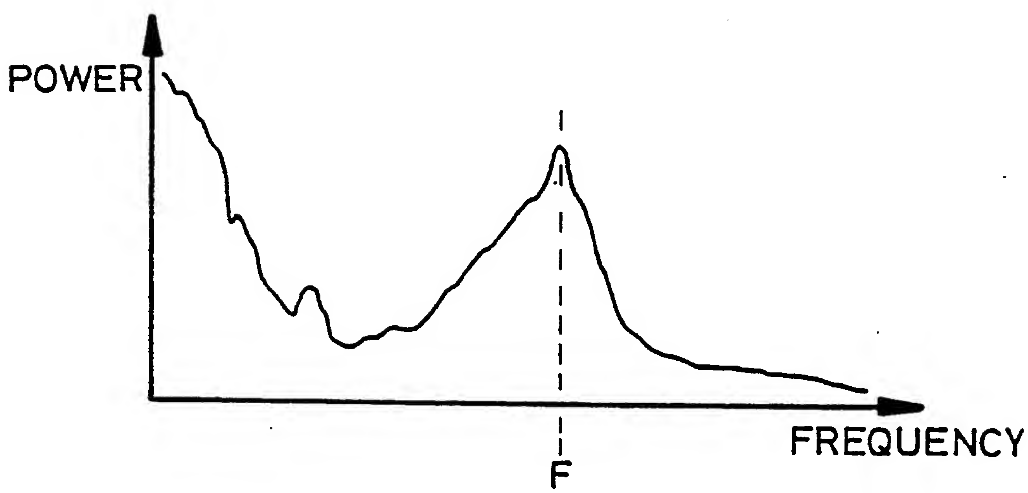


Fig.2

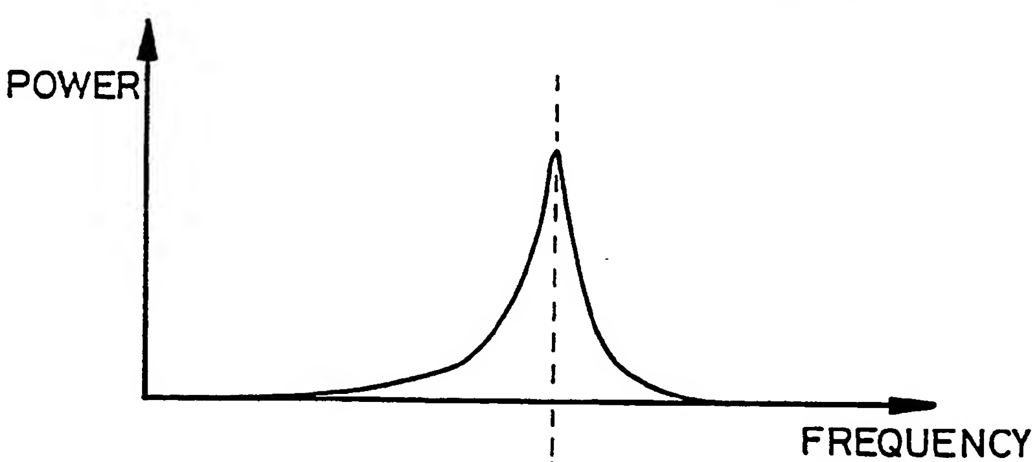


Fig.3

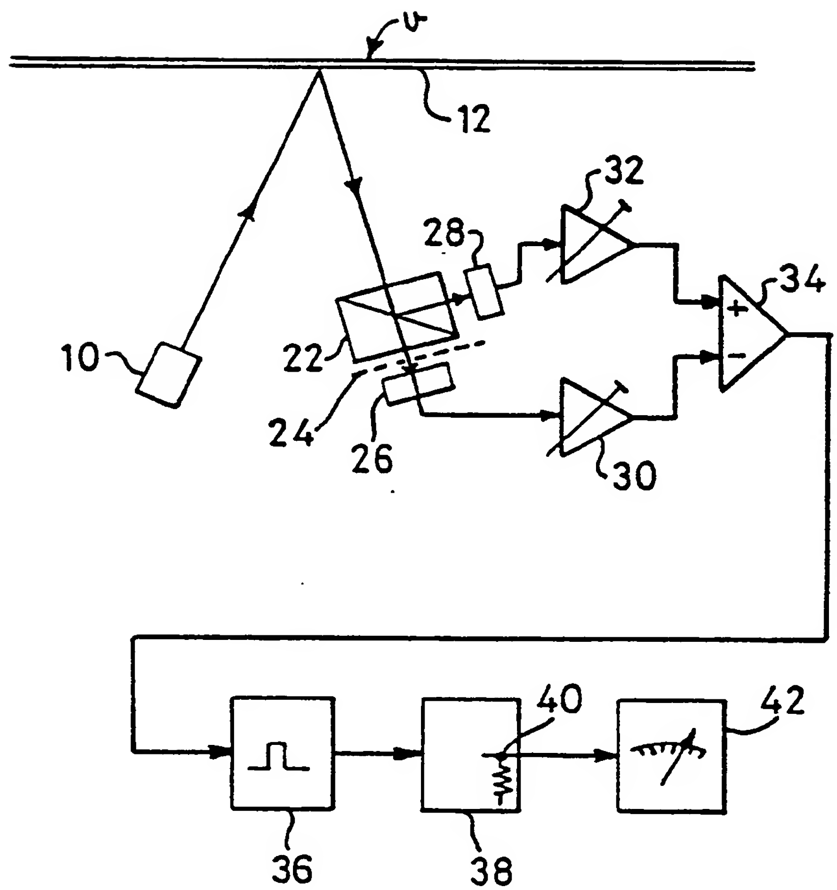


Fig.4

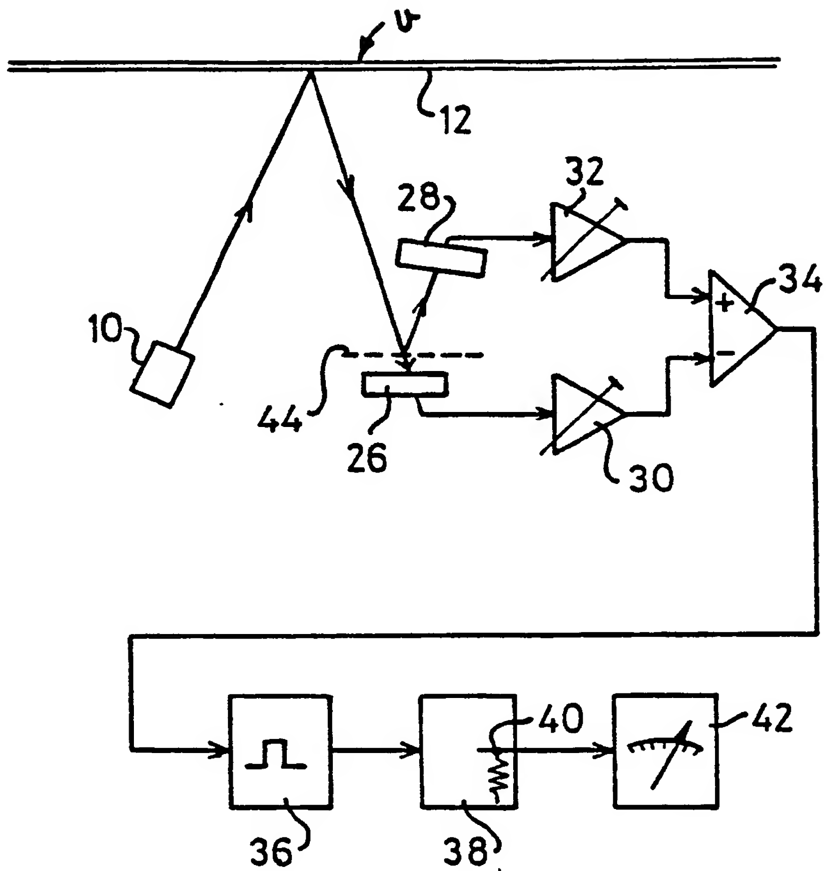


Fig. 5

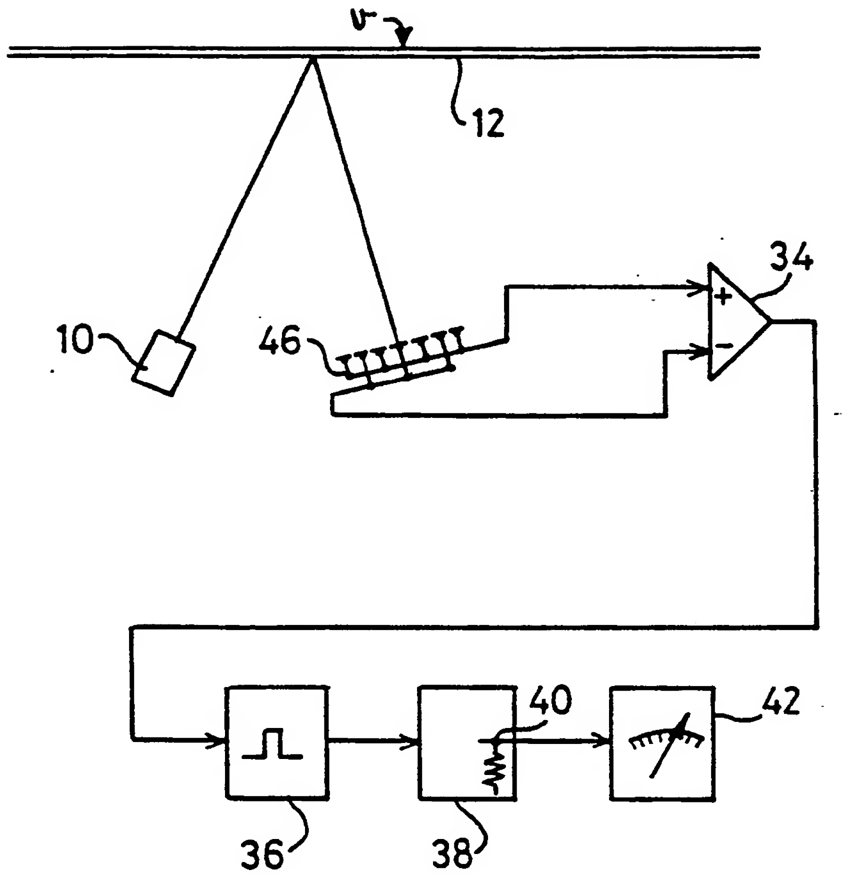


Fig. 6

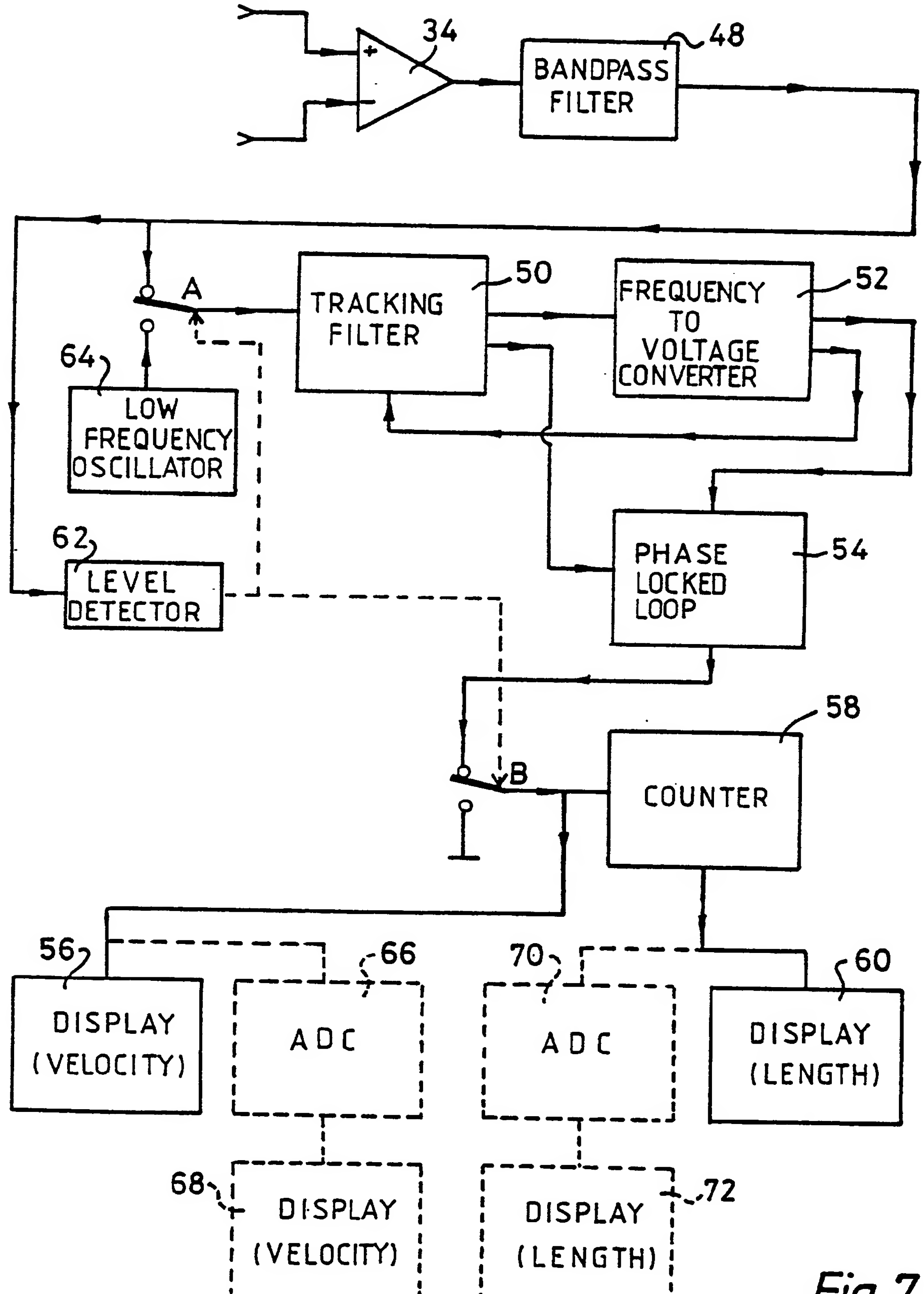
34
48
BANDPASS FILTER
A
TRACKING FILTER
50
FREQUENCY TO VOLTAGE CONVERTER
52
64
LOW FREQUENCY OSCILLATOR
62
LEVEL DETECTOR
PHASE LOCKED LOOP
54
58
B
COUNTER
56
DISPLAY (VELOCITY)
66
ADC
70
ADC
60
DISPLAY (LENGTH)
68
DISPLAY (VELOCITY)
DISPLAY (LENGTH)
72

Fig.7

# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 86/00246

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

$IPC^4$: G 01 S 17/58; G 01 S 7/48

**II. FIELDS SEARCHED**

Minimum Documentation Searched [7]

| Classification System | Classification Symbols |
|---|---|
| $IPC^4$ | G 01 S; G 01 P; G 02 B |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [9]

| Category [*] | Citation of Document, [11] with indication, where appropriate, of the relevant passages [12] | Relevant to Claim No. [13] |
|---|---|---|
| | FR, A, 2044366 (P.G.H. SCHNERB) 19 February 1971 | |
| X | see page 35, lines 4-32; figures 21-24 | 1,2,14,15 |
| Y | | 3,11-13 |
| | -- | |
| Y | US, A, 3955882 (R.G.T. NEILSON et al.) 11 May 1976 see column 2, lines 53-62 | 12,13 |
| | -- | |
| Y | GB, A, 1330163 (BRITISH AIRCRAFT) 12 September 1973 see page 1, lines 31-41; page 1, line 48 - page 2, line 8; page 2, lines 63-83; figure 3 | 3,11 |
| | -- | |
| | Patents Abstracts of Japan, no. 3386, E76 & JP, A, 51147364 (Mitsubishi) | |
| X | 17 December 1976, see the whole abstract | 1 |
| Y | | 2 |
| A | | 3,5,7,11, 22-24 |
| | -- ./. | |

* Special categories of cited documents: [10]

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 11th August 1986 | 22 SEP 1986 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| EUROPEAN PATENT OFFICE | L. ROSSI |

Form PCT/ISA/210 (second sheet) (January 1985)

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
|---|---|---|
| Y | Nachrichtentechnische Zeitschrift, NTZ, vol. 35, no. 1, January 1982 (Berlin, DE) H. Herbrig: "Berührungslosarbeitendes Wegmesssystem", pages 6-11, see the whole document | 2 |
| A | | 3,4,6,7,9-11 16-24 |
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| | -- | |
| A | US, A, 4227076 (J. HERMANN) 7 October 1980 see the abstract; figures 1,2 | 1-3,8,11 |
| | -- | |
| A | US, A, 3432237 (R.A. FLOWER et al.) 11 March 1969 see columns 7,8; claims 1-3; figures 1-3 | 1,2 |
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 86/00246 (SA 13195)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 08/09/86

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

| Patent document cited in search report | Publication date | Patent family member(s) | | Publication date |
|---|---|---|---|---|
| FR-A- 2044366 | 19/02/71 | None | | |
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| | | FR-A,B | 2148568 | 23/03/73 |
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| US-A- 3432237 | 11/03/69 | DE-A- | 1523179 | 02/04/70 |
| | | FR-A- | 1433654 | |
| | | GB-A- | 1043791 | |

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82